National Aeronautics and Space Administration

Quantum Computer Project

Accelerating Advanced Computing for NASA Missions

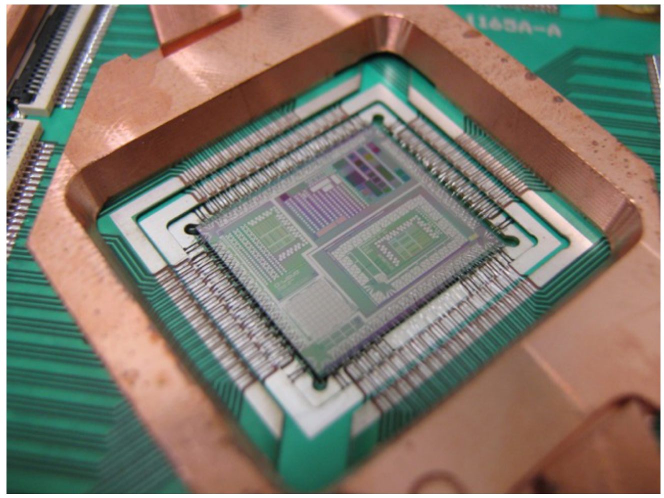
NASAfacts

NASA's quantum computing project is an experiment to assess the potential of quantum computers to perform calculations that are difficult or impossible to solve accurately using conventional supercomputers in a realistic timeframe. The project is a collaboration among teams at NASA, Google, and the Universities Space Research Association (USRA).

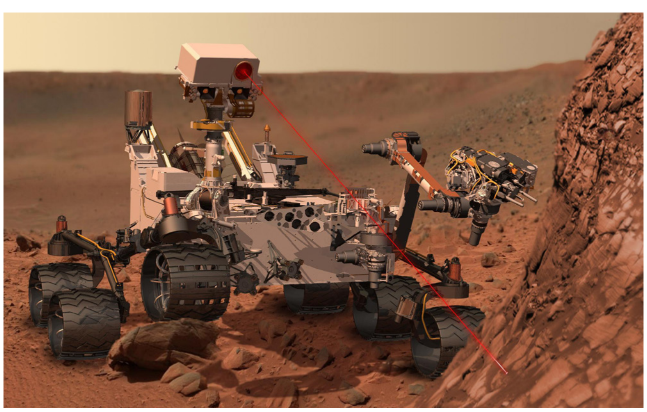
The NASA team aims to demonstrate that quantum computing and quantum algorithms may someday dramatically improve the agency's ability to solve difficult optimization problems for aeronautics, Earth and space sciences, and space exploration missions.

Quantum computing is based on quantum bits, or qubits. Unlike traditional computers, in which bits must have a value of either zero or one, a qubit can represent a zero, a one, or both values simultaneously. Representing information in qubits allows the information to be processed in ways that have no equivalent in classical computing, taking advantage of phenomena such as quantum tunneling and quantum entanglement. With qubit states, quantum computers may theoretically be able to solve certain problems in a few days that would take millions of years on a classical computer.

NASA researchers are conducting initial studies using the D-Wave Two™ system that began operation in September 2013. The system is located in the NASA Advanced Supercomputing (NAS) facility's Quantum Artificial Intelligence Laboratory (QuAIL) at NASA's Ames Research Center, Moffett Field, Calif. Currently, it is the most powerful system of its kind in the world, with 512 superconducting flux qubits. The D-Wave Vesuvius™ processor is housed inside a cryogenics system within a 10-square-meter box that blocks out the Earth's magnetic field. The D-Wave Two system is an analog optimizer. As such, the NASA team has determined that it is best applied to hard problems of interest to NASA where parallel processing is inefficient.



The D-Wave superconducting 512-qubit Vesuvius processor chip.



Researchers are studying the potential of quantum computers to assist in operational planning for missions such as NASA's Mars Curiosity rover.

Early research studies are focusing on quantum approaches to optimization problems in applications such as air traffic control; machine autonomy, verification, and validation; and mission planning and scheduling. Specific examples include:

- Advanced diagnosis and fault management in engineering systems, for example, the detection of multiple faults in complex electrical power networks such as those in the International Space Station (ISS).
- Automated mission planning to determine the best use of limited resources—including time and electrical power—for ongoing space missions such as the Mars Science Laboratory rover Curiosity and the ISS, as well as future space missions with multiple rovers.

- Development of scheduling algorithms to efficiently and automatically determine the optimal time for making Low Earth Orbit satellite observations; and to determine aircraft flight routes and landing sequences in airports, taking into account weather conditions and air traffic management priorities.
- Evaluation of the fundamental comparative advantages of quantum optimization on hard computational problems (such as spin-glass magnets) against classical algorithmic methods.

In addition to these studies, the broader academic community, through USRA, will utilize the D-Wave Two system to conduct research on algorithms and advanced programming techniques for quantum annealing, with the objective to advance the state-of-the-art in quantum computing and its application to artificial intelligence.

Through a five-year, non-reimbursable Space Act Agreement between NASA, Google, and USRA, the project team will conduct four main technology tasks: quantum computer acceptance tests; development of quantum AI algorithms and mapping them onto the system; development of problem decomposition and hardware embedding techniques; and creating quantum-classical hybrid algorithms.

The first results from NASA's experiments in applying early quantum annealers to problems related to practical applications have appeared in a series of 2014 technical reports and publications. These initial results are providing insight into architectural considerations and programming practices for future quantum annealing devices. Scientists expect that quantum computing will vastly improve a wide range of tasks that can lead to new discoveries and technologies, significantly changing the way we solve real-world problems.

Flight controllers at the PHALCON (Power, Heating, Articulation, Lighting Control Officer) console at NASA's Mission Control Center at Johnson Space Center manage the electricity available to operate the International Space Station systems and experiments.

For more information about the quantum computer, visit:
http://www.nas.nasa.gov/quantum

For more information about NASA's partnership with Google and USRA, visit:
https://plus.google.com/+QuantumAILab/
http://www.usra.edu/quantum/

For information on USRA's request for proposals for Cycle 1 of the Quantum Artificial Intelligence Laboratory Research Opportunity, visit:
http://www.usra.edu/quantum/rfp/

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